Homeworks 4

Exercise 1

- Which is the pH of a solution 0.01M of ammonia? ($Kb=1.8\cdot10^{-5}$ M at 25°C)

$$NH_3 \leftrightarrows NH_4^+ + OH^-$$

Ammonia is a weak base, hence we can calculate $[OH^-]$:

$$[OH^-] = \sqrt{(Kb \cdot Cb)} = \sqrt{(1.8 \cdot 10^{-5} \cdot 0.01)} = 4.24 \cdot 10^{-4}$$

$pOH = -\log(4.24\cdot10^{-4}) = 3.37$
$pH = 14 – 3.37 = 10.63$

Exercise 2

Calculate the Ka of a weak monoprotic acid whose 0.1 M solution has pH= 3.0.

$AH + H_2O \leftrightarrows A^- + H_3O^+$

$[H_3O^+] = 10^{-pH} = 10^{-3}$ M

$Ka = [H_3O^+]^2 / Ca = 10^{-6} / 10^{-1} = 10^{-5}$

Exercise 3

Calculate the molar concentration of a solution of ammonia ($K_b = 1.8 \cdot 10^{-5}$M at 25°C) and the concentration of hydroxyls, given that $\alpha = 1.3 \cdot 10^{-2}$.

$$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$$

$Kb = Cb \cdot \alpha^2 / (1-\alpha)$

$\rightarrow Cb = Kb \cdot (1-\alpha) / \alpha^2 = 1.8 \cdot 10\text{-}5 \cdot 0.987 / 1.69 \cdot 10\text{-}4 = 0.105$ M

$[OH^-] = Cb \cdot \alpha = 0.105 \cdot 1.3 \cdot 10\text{-}2 = 1.36 \cdot 10^{-3}$ M

Exercise 4

Calculate the pH of a solution made by mixing 25ml of KOH 0.01 N with 75ml of HNO_3 0.01 N.

$$KOH + HNO_3 \leftrightharpoons KNO_3 + H_2O$$

n_{eq} base = N·V = $10^{-2} \cdot 25 \cdot 10^{-3} = 2.5 \cdot 10^{-4}$ eq

n_{eq} acid = N·V = $10^{-2} \cdot 75 \cdot 10^{-3} = 7.5 \cdot 10^{-4}$ eq

There is an excess of acid, therefore the pH will be <7

n_{eq} acid = n_{eq} acid - n_{eq} base = $7.5 \cdot 10^{-4} - 2.5 \cdot 10^{-4} = 5 \cdot 10^{-4}$ eq

pH = $-\log(5 \cdot 10^{-4}) = 3.3$

Exercise 5

Calculate the dissociation coefficient of a methanoic acid solution $5 \cdot 10^{-3}$ M (Ka= $2 \cdot 10^{-4}$M).

$HCOOH \leftrightarrows HCOO^- + H^+$

$Ka = Ca \cdot \alpha^2 /(1-\alpha) \rightarrow Ca \cdot \alpha^2 - Ka(1-\alpha) = 0$

$5 \cdot 10^{-3} a^2 + 2 \cdot 10^{-4} a - 2 \cdot 10^{-4} = 0$

$5 a^2 + 0.2 a - 0.2 = 0$

$$\alpha = \frac{-0.2 \pm \sqrt{(0.04 + 4)}}{10} = 0.18$$

Exercise 6 = 3

Kb of ammonia is $1.8 \cdot 10^{-5}$ M at 25°C. Calculate the molar concentration of ammonia and of hydroxide anions in a solution in which ammonia is 1.3% dissociated.

$$NH_3 \leftrightarrows NH_4^+ + OH^-$$

$Kb = Cb \cdot \alpha^2 / (1-\alpha)$

$\rightarrow Cb = Kb \cdot (1-\alpha) / \alpha^2 = 1.8 \cdot 10\text{-}5 \cdot 0.987 / 1.69 \cdot 10\text{-}4 = 0.105$ M

$[OH^-] = Cb \cdot \alpha = 0.105 \cdot 1.3 \cdot 10\text{-}2 = 1.36 \cdot 10^{-3}$ M

Exercise 7

Calculate the concentration of a solution of a weak acid knowing that it is 0.1% dissociated and its pH is 5.0.

$$AH + H_2O \leftrightarrows A^- + H_3O^+$$

$$[H_3O^+] = Ca \cdot \alpha \quad \rightarrow Ca = [H_3O^+] / \alpha = 10^{-5} / 10^{-3} = 10^{-2}\ M$$

Exercise 8

Ka of HCN is $4 \cdot 10^{-10}$ M at 25°C. Calculate the molar concentration of the undissociated acid and the pH of the solution in which 0.01% of HCN is dissociated.

$$HCN \leftrightarrows CN^{-} + H^{+}$$

$Ka = Ca \cdot \alpha^{2} / (1-\alpha)$

$\rightarrow Ca = Ka \cdot (1-\alpha) / \alpha^{2} = 4 \cdot 10^{-4} \cdot (1-10^{-4}) / 10^{-8} = 0.0399 = 0.04$ M

$[H3O^{+}] = Ca \cdot \alpha = 4 \cdot 10^{-6} \quad \rightarrow pH = 5.39$

Exercise 9

A solution of ammonium chloride has pH=5.3. Calculate the concentration of the salt in solution. (Kb=$1.8\cdot10^{-5}$ M at 25°C)

$$NH_4Cl \rightarrow Cl^- + NH_4^+$$

$$NH_4^+ + H_2O \leftrightarrows NH_3 + H_3O^+$$

$$K_i = \frac{K_w}{K_b} = \frac{[H_3O^{+1}]^2}{Cs}$$

$$Cs = [H_3O^{+1}]^2 \cdot \frac{Kb}{Kw} = \frac{(5\cdot10^{-6})^2\cdot1.8\cdot10^{-5}}{10^{-14}} = 0.045\text{M}$$

Exercise 10

A solution of Lithium hydrogen carbonate, made by dissolving 7.6 mg of salt in 1 L of water, has pH=8.2. Calculate the values of Ki and Ka.

$LiHCO_3 \rightarrow Li^+ + HCO_3^-$

$HCO_3^- + H_2O \leftrightarrows H_2CO_3 + OH^-$

Cs = g /(FW·V) = 7.6·10-3 / 6.9·1 = 1.1 mM

pOH = 14 – pH = 14-8.2 = 5.8 $\rightarrow$ $[OH^-] = 10^{-5.8} = 1.58 \cdot 10^{-6}$ M

$Ki = Kw / Ka = [OH^-]^2 / Cs = (1.58 \cdot 10^{-6})^2 / 1.1 \cdot 10^{-3} = 1.44 \cdot 10^{-9}$

$Ka = Kw / Ki = 10^{-14} / 1.44 \cdot 10^{-9} = 6.94 \cdot 10^{-6}$

Exercise 11

Calculate the pH of a solution of ammonium chloride made by 10^{-4} mol of NH_4^+ in 100 ml of solution. ($Kb = 1.8 \cdot 10^{-5}$ M at 25°C)

$$NH_4Cl \rightarrow Cl^- + NH_4^+$$

$$NH_4^+ + H_2O \leftrightarrows NH_3 + H_3O^+$$

$$[H_3O^{+1}] = \sqrt{Ki \cdot Cs} = \sqrt{\frac{Kw \cdot Cs}{Kb}} = \sqrt{\frac{10^{-14} \cdot 10^{-3}}{1.8 \cdot 10^{-5}}} = \sqrt{5.5 \cdot 10^{-13}} = 7.4 \cdot 10^{-7}$$

pH = -log 7.4·10-7 = 6.13